Proteins and nucleic acids: a new generation of flame retardants?

Jenny Alongi,
Federico Carosio, Alessandro Di Blasio, Fabio Cuttica, Giulio Malucelli
Politecnico di Torino, Dipartimento di Scienza Applicata e Tecnologia,
jenny.alongi@polito.it

POLITECNICO DI TORINO

World Fire Statistics Bulletin

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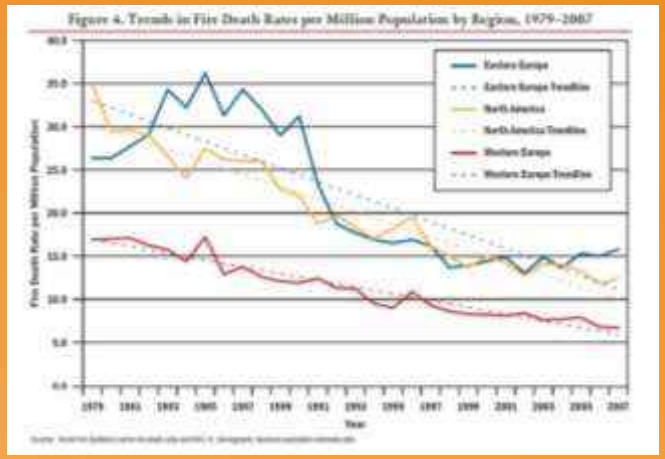
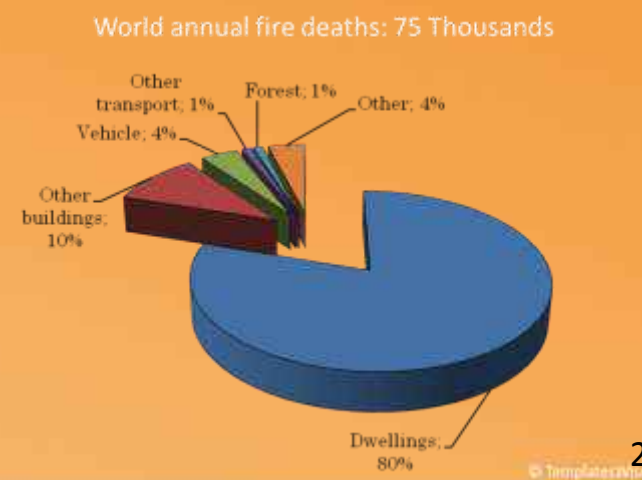
Table 4: Population comparisons for fire deaths (2007-2009)

Deaths per 100,000 persons

Country	Deaths per 100,000 persons (2007-2009)
Singapore	0.05
Switzerland	0.33
Italy	0.46
Netherlands	0.46
Austria	0.47
Spain	0.54
Slovenia	0.59
Germany	0.60
Portugal	0.61
United Kingdom	0.76
Canada	0.77
Australia	0.79
New Zealand	0.82
France	0.96
United States	1.17
Ireland	1.19
Belgium	1.21 [2004]
Czech Republic	1.30
Norway	1.33
Sweden	1.37
Denmark	1.41
Greece	1.41
Poland	1.53
Japan	1.57
Barbados	1.65 [2007-2008]
Hungary	1.68
Romania	1.86
Finland	1.98

NOTE: Population figures derived from United Nations Department of Economic and Social Affairs, Population Division website.





POLYMER COMBUSTION CYCLE

Flame retardants

GAS PHASE

Volatiles

Products (CO_2, CO…)

Oxygen

Dispersion

Heat

Polymer

Char

Flame retardants

CONDENSED PHASE

FLAME RETARDANTS:

SPECIES ABLE TO DELAY OR SLOW DOWN COMBUSTION BEFORE FIRE IS FULLY DEVELOPED

✓ Halogen and metal-halogen derivatives

PERSISTENT, BIOACCUMULATIVE, AND/OR ENVIRONMENTALLY TOXIC FOR ANIMALS AND HUMANS

- ✓ Inorganic hydroxides
- ✓ Phosphorous compounds

BULK

- ✓ Intumescent system
- ✓ Polymer nanocomposites

BULK and SURFACE

INNOVATIVE APPLICATIONS

MEDICINE & DRUGS

DEFENCE & SECURITY

ENERGY

NANODEVICES

COSMETICS

NANOBIOTECHNOLOGY

BIOENGINERING

TEXTILE

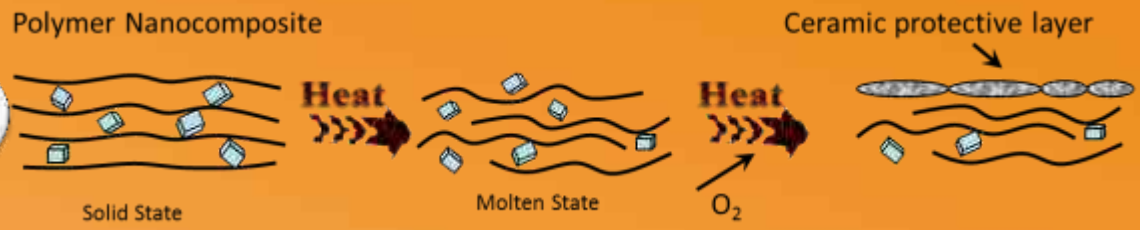
OPTICAL ENGINERING

TEXTILE & FLAME RETARDANCY

NANOTECHNOLOGY IN TEXTILE

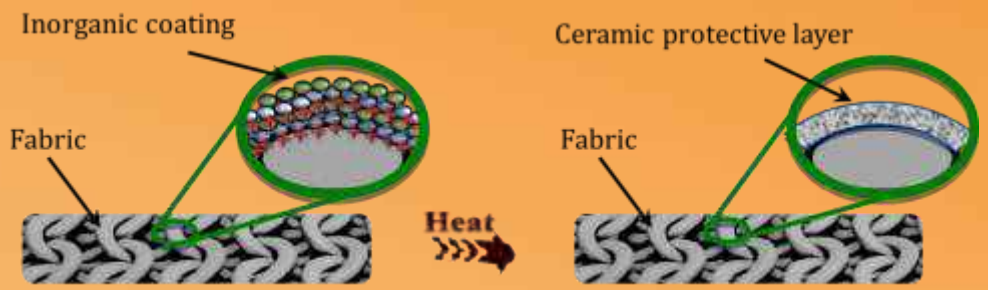
POLYMER NANOCOMPOSITES: 1ST STRATEGY

NANOSTRUCTURING SYNTHETIC FIBRES

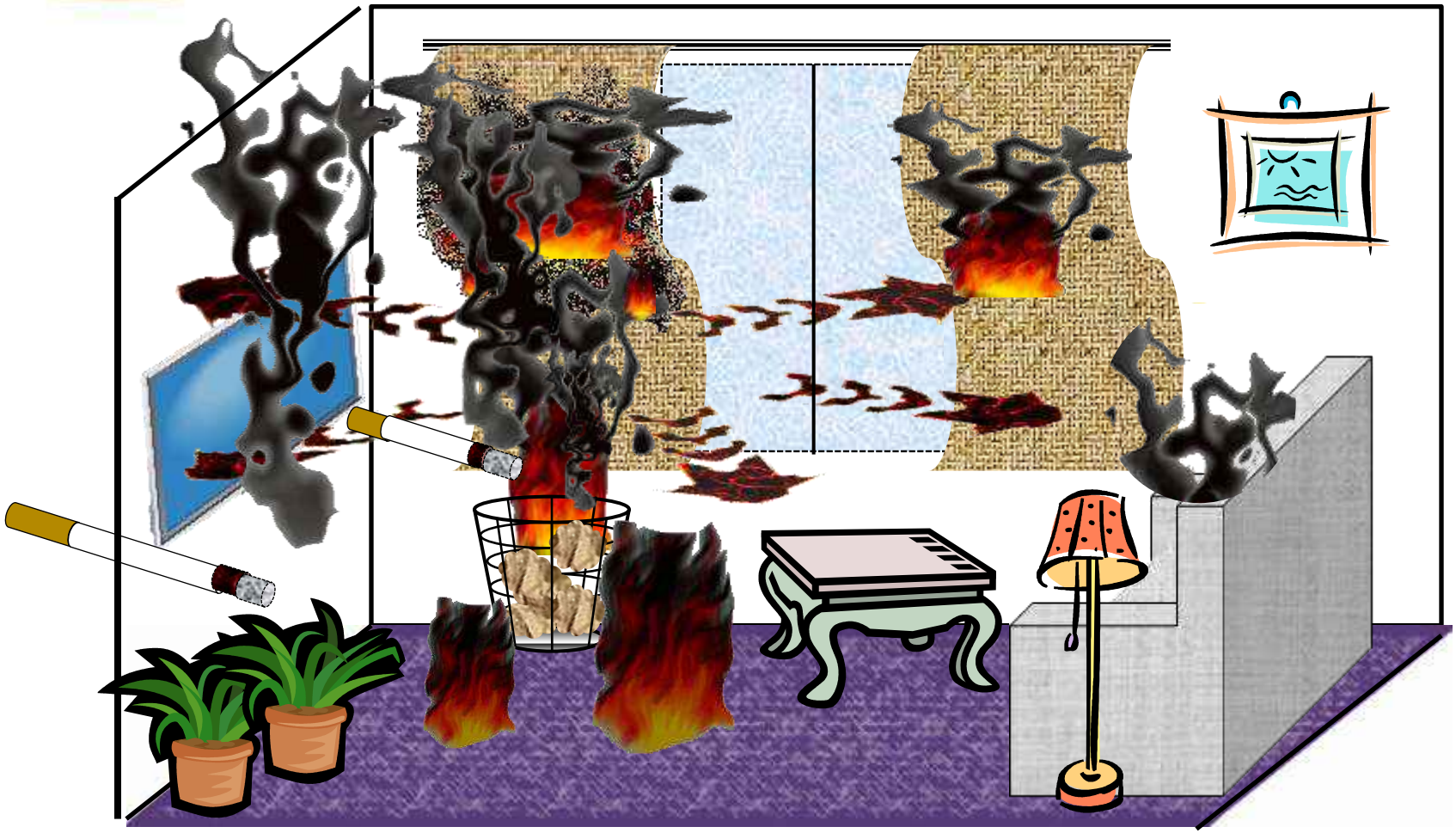


A COATING ABLE TO ACT AS BARRIER TO HEAT AND OXYGEN MIMICKING WHAT OCCURS IN POLYMER NANOCOMPOSITES: 2ND STRATEGY

SMART NANOCOATINGS



HOME FIRE SCENARIO



FLAME RETARDANCY

RESISTANCE TO A FLAME APPLICATION

- Ignitability
- Ease of extinction
- Burning rate
- Damaged area

RESISTANCE TO AN IRRADIATIVE HEAT FLUX

- Resistance to a Radiating Heat
- Heat Release
- Burning rate
- Time To Ignition
- Smokes
- CO and CO_2
- Final residue

RESISTANCE TO A FLAME APPLICATION

VERTICAL FLAME SPREAD TESTS

ISO 4589

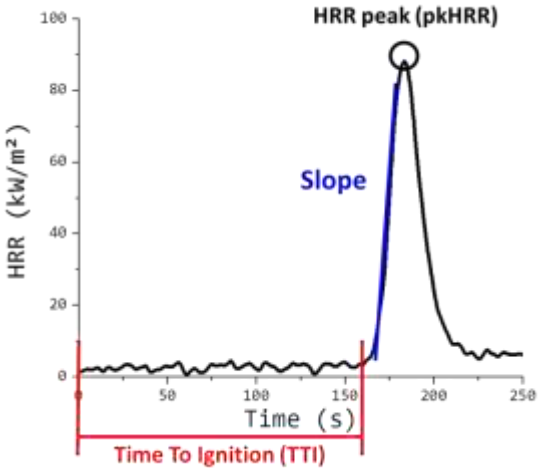
ASTM D6413

HORIZONTAL FLAME SPREAD TESTS

ISO 9239

RESISTANCE TO AN IRRADIATIVE HEAT FLUX

CONE CALORIMETER
ISO 5660



HRR, *Heat Release Rate*

THR, *Total Heat Release*

TTI, *Time To Ignition*

TSR, *Total Smoke Release*

OD, Optical Density

Mass or residue

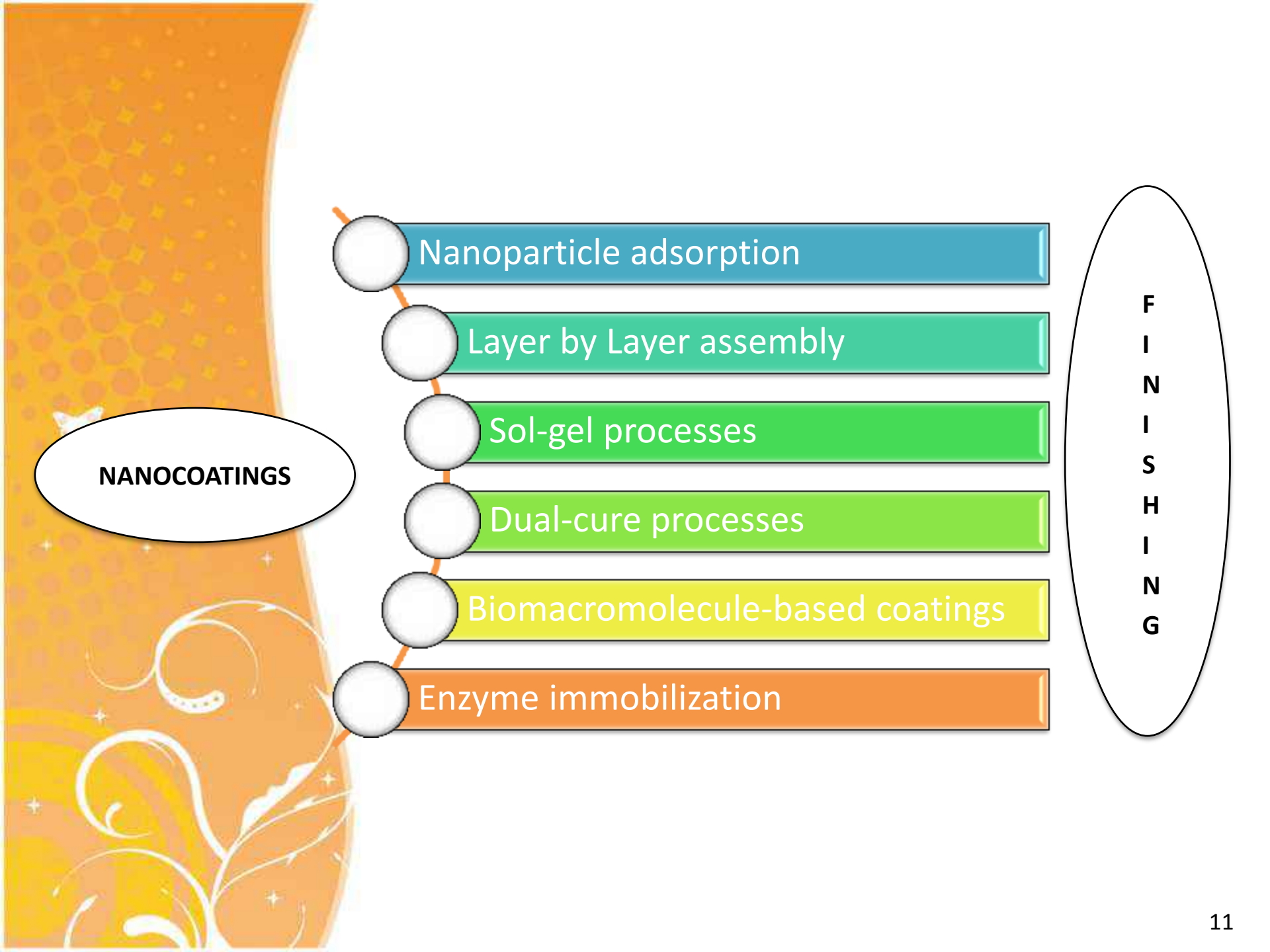
CO_2 and CO amount

SMOKE DENSITY CHAMBER
ISO 5659 or ASTM E662

TSR, *Total Smoke Release*

OD, Optical Density

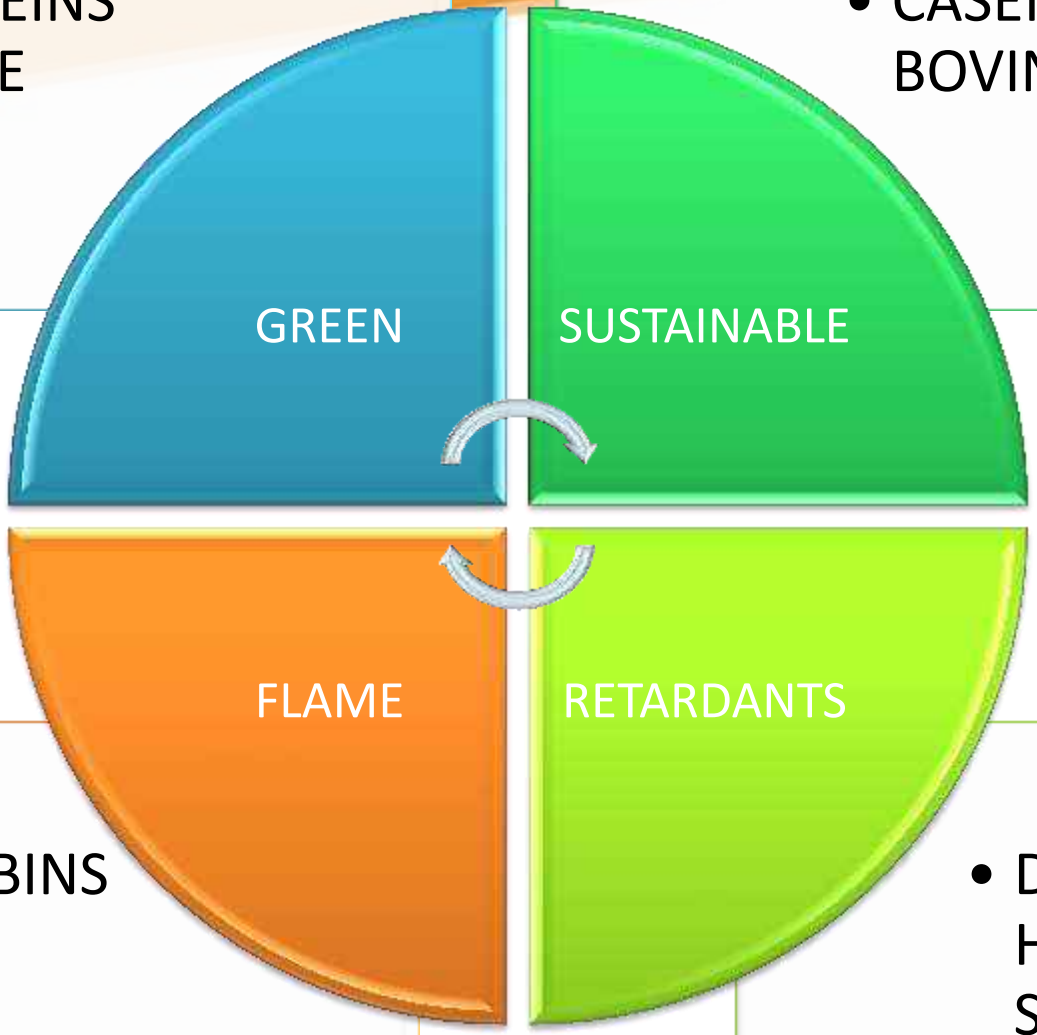
CO_2 and CO amount


NANOCOATINGS
Nanoparticle adsorption
Layer by Layer assembly
Sol-gel processes
Dual-cure processes
Biomacromolecule-based coatings
Enzyme immobilization
FINISHING

BIOMACROMOLECULE-BASED COATINGS

- WHEY PROTEINS from BOVINE MILK

- CASEINS from BOVINE MILK



- HYDROPHOBINS from FUNGI

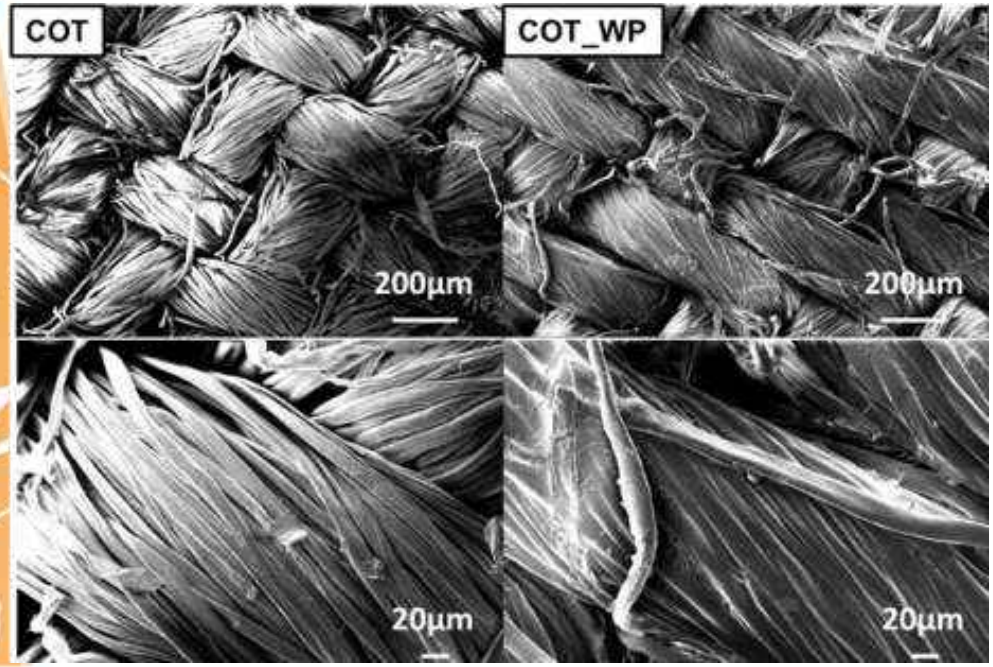
- DNA from HERRING SPERM

WHEY PROTEINS

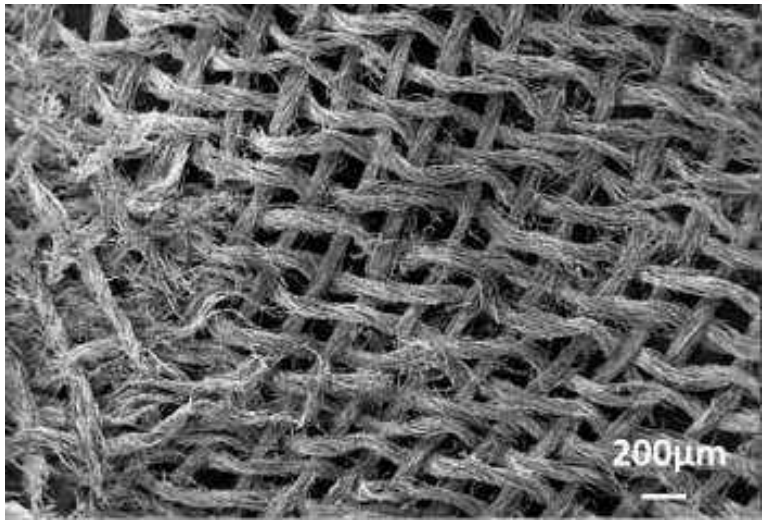
Whey Protein (WP) components: α-lactalbumin and β-lactoglobulin

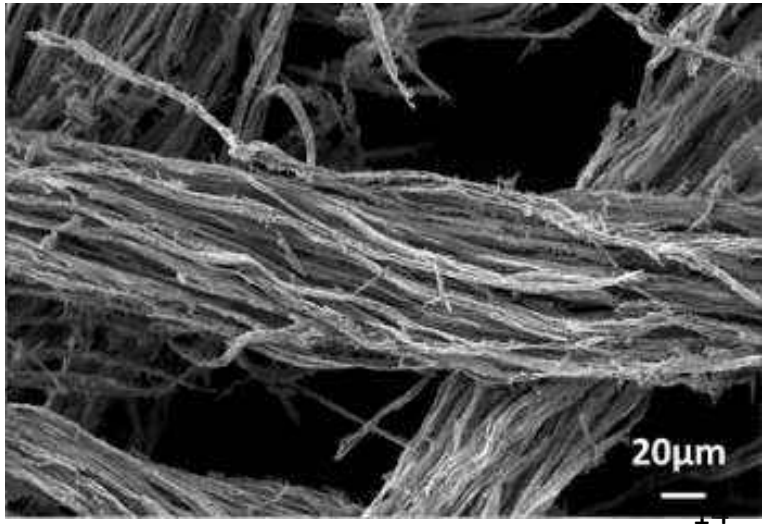
- WP components have been widely studied for their potential use as agents able to form edible and **biodegradable films** based on a **waste** stream from the **cheese industry**

A coating consisting of WP could play a key role in the flame retardancy



FLAMMABILITY TESTS IN HORIZONTAL CONFIGURATION





Sample	Burning time [s]	Burning rate [mm/s]	Residue [%]
COT	78	1.5	-
COT_WP	126	1.0 (-33%)	30

CASEINS

- ✓ **PHOSPHOPROTEINS** with a micelle structure, containing 80% of the total protein content of milk, and mainly consisting of **α-casein**, **β-casein** and **κ-casein**,
- ✓ the **main product of dairy industry** with a high nutritional product,
- ✓ used for a long time in non-food applications, particularly as a binding material for plastics, man-made fibres, coatings and dyes.

SAMPLE	BURNING TIME [s]	BURNING RATE [mm/s]	RESIDUE [%]	LOI [%]
COT	78	1.3	-	18
COT_C	75	0.4 (-69%)	86	24

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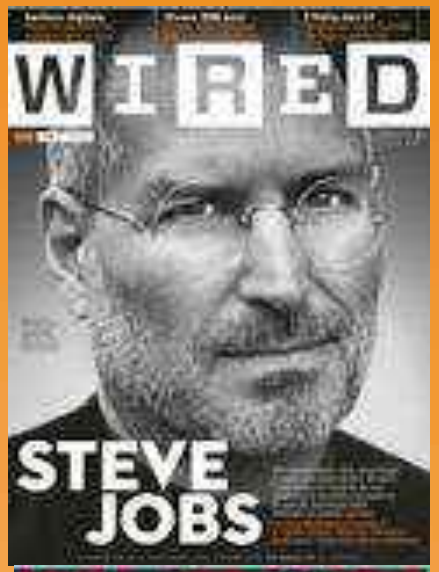
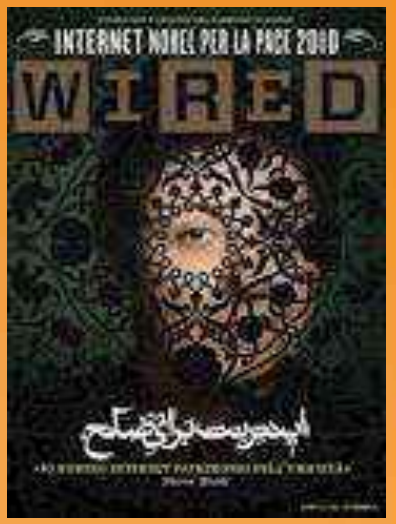
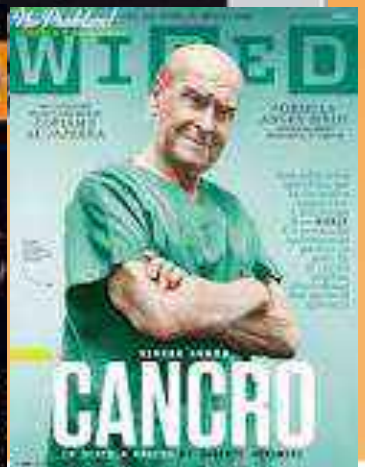
Storie idee e persone che cambiano il mondo







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SCIENCE | biology | tech

Can't Burn This: DNA Shows Surprising Flame-Retardant Properties

BY NADIA DRAKE 03.11.13 1:50 PM

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Fireproof coatings made from DNA

1 March 2013 Ian Farrell

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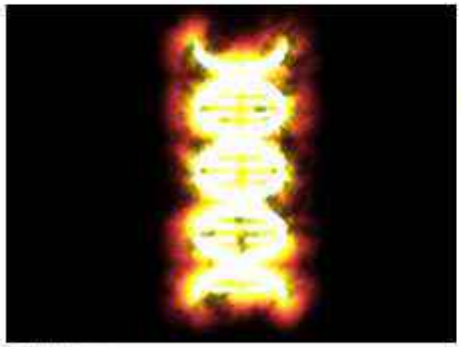

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A new type of flame-retardant coating for textiles has been developed from a most unlikely source. Researchers from Italy have used DNA, extracted from herring sperm, to fireproof samples of cotton, and have found its performance to be on a par with commercially manufactured materials.'

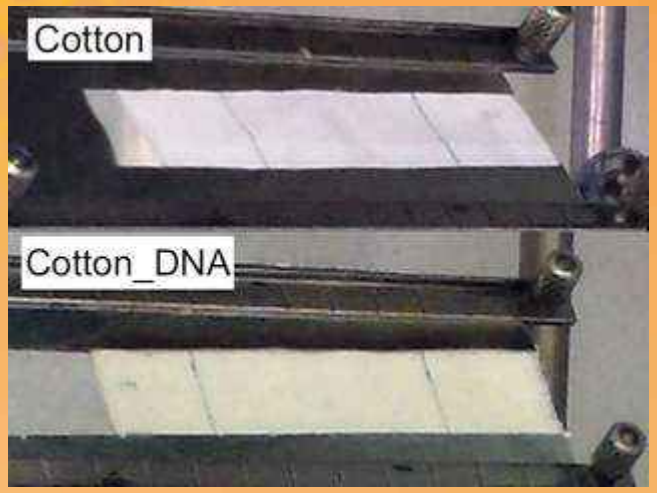
The flame retardant industry is big business (one recent study estimates 465,000 tones to have been produced in Europe during 2006[1]), but many of the chemicals used are hazardous to the environment. Traditional halogenated flame retardants tend to bioaccumulate and are toxic to animal and human health, hence their use is becoming increasingly restricted in both the EU and US. DNA, on the other hand, is abundant, naturally occurring, and biodegradable – and just happens to have all of the characteristics of a classic flame-retardant chemical.

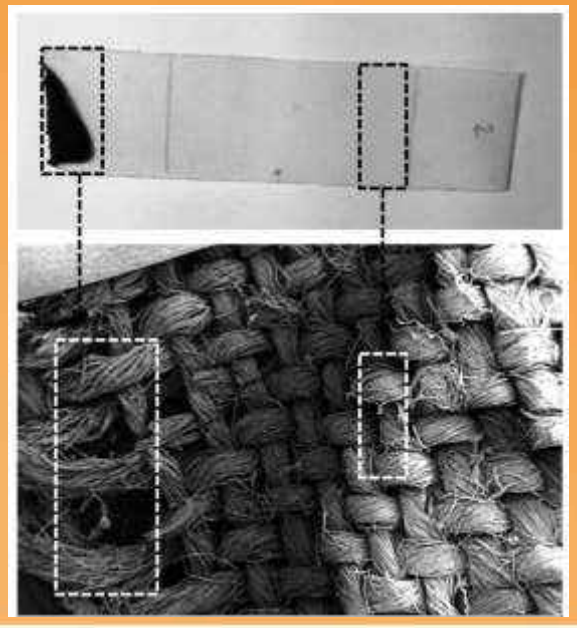
Giulio Malucelli, Politecnico di Torino, who leads the research group that is developing the DNA coating, explains that an intumescent material reacts in three ways when it is exposed to fire. 'Firstly, carbon sources act as thermal insulators, producing char and limiting the production of volatile substances,' he says. 'Secondly, sources of acid dehydrate cellulose, producing carbon and adding to the char. Lastly, a blowing agent releases non-combustible gas, such as water vapour, ammonia or carbon dioxide, forming a physical barrier towards oxygen.'

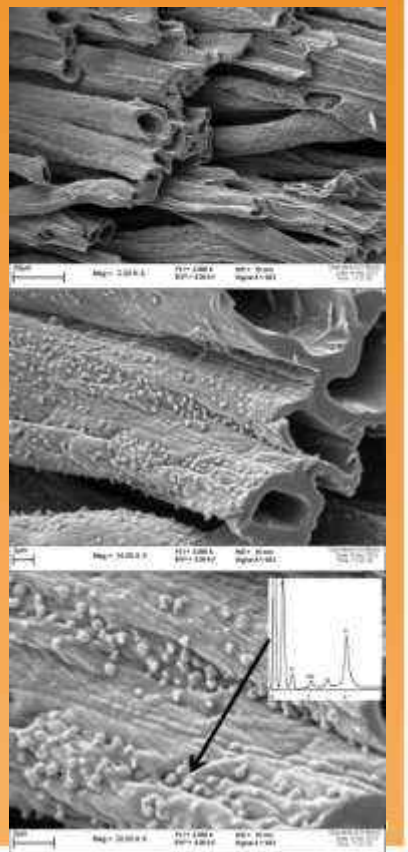
DNA:
a novel and green flame retardant for cotton

DNA is composed of two long chain polymers of nitrogen-containing bases: adenine (A), guanine (G), cytosine (C) and thymine (T) with backbones made of sugars and phosphate groups connected through ester bonds.

DNA can be considered an all-in-one intumescent material

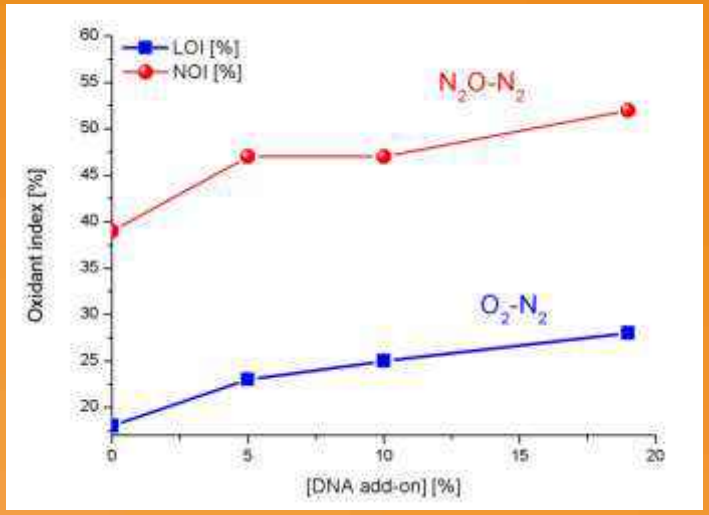






LOI and NOI TESTS

Sample	Oxidant Index [%]	
	LOI	NOI
COT	18	39
COT_DNA_5%	23	47
COT_DNA_10%	25	47
COT_DNA_19%	**28**	**52**



CONE CALORIMETRY

NO IGNITION UNDER A HEAT FLUX OF 35kW/m²

Conclusions:

…… probably mimicking nature, the best results may be achieved….

Politecnico di Torino, Alessandria branch
Department of Applied Science and Technology (DISAT)

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